# POTENTIAL HIGH VALUED OPPORTUNTITIES BUILDING BLOCK PROFILE[1]

Prepared for:

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# BUILDING BLOCKS FOR ECONOMIC DEVELOPMENT & ANALYSIS

## PREFACE

### PURPOSE

Building Blocks have been conceived and developed by the Economic Development Branch of the Ministry of Sustainable Resource Management, under the guidance of Nancy South, Manager Economic Analysis, as an analytical tool that supports British Columbia coastal and land and resource use planning and decision-making and economic development initiatives. The Blocks contain concise business and sector information for a broad range of resource-based business types in BC. At this point, there are more than 30 Blocks either complete or in draft form. Several more Blocks have been identified as high priority by planning tables and other client groups. Additional Building Blocks will be developed over time, and some Blocks may be updated. For the most current Building Blocks, please see the Ministry of Sustainable Resource Management website, at: http://srmwww.gov.bc.ca/rmd/ecdev/

### ACKNOWLEDGEMENTS

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### BENEFITS

Building Blocks are expected to provide the following general benefits:

- Increase efficiency and more informed decision-making by providing readily accessible, credible information to planning and economic development processes;
- Improve the consistency of economic information across planning areas;
- Support economic analysis and decision-making that occurs outside formal coastal and land use planning processes; and
- Provide linkages between economic analysis and other social and environmental analytical tools (through identifying resource requirements to support economic activities and general compatibilities with other sectors and values).

### LIMITATIONS

Every effort has been made to ensure that the information contained in Building Blocks is accurate and consistent. Approved, credible data sources are the foundation for Building Blocks. All Blocks were reviewed by sponsoring agencies and other experts. However, users are cautioned that information is used at their own risk, and that the authors and sponsors are not liable for any damages. Any conclusions or interpretations by the authors are not intended to represent government policy. Also, note that Building Blocks do not provide site specific information nor do they consider requirements for sustainability (social, community, environmental).

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### RECOMMENDED REFERENCE/CITATION

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The High Valued Mineral Product Building Block describes mineral processing opportunities selected on the basis of their significant downstream processing potential and value-added manufacturing activity. The three selected high value opportunities discussed below are: – Phosphate Fertilizer, Magnesium Metal and Diamonds.

# PHOSPHATE

## 1.0 OVERVIEW

### 1.1 Introduction

- Phosphate rock (i.e., apatite) is the major industrial source of phosphorus, which is an essential element for plant and animal health – phosphorus is often a limiting factor in the growth of plants and is critical to early season growth under cool, moist soil conditions.[2]
- About 90 percent of the phosphate rock production is used for fertilizer – phosphate is a valued fertilizer component of the nitrogen[3]-phosphorus-potassium[4] fertilizer group used throughout the world – the remaining 10 percent is used in detergents, food, drinks, dental products, and various chemicals.
- In its natural state, phosphate rock is not very soluble so it provides little available phosphorus to plants – to process phosphate rock it must be treated with large amounts of sulfuric acid to make phosphoric acid – phosphate fertilizers include diammonium phosphate (DAP), and monoammonium phosphate (MAP).[5]
- Although, the United States is the world's leading producer and consumer of phosphate rock, surface deposits of phosphates are widely distributed throughout the world. [6]

### 1.2 BC History

- BC has large deposits of phosphate rock particularly in the Fernie and Tumbler Ridge areas[7] – however, BC's known deposits are of a lower grade than phosphate rock mined in the US and Ontario – however, BC's deposits may able to meet fertilizer plant specifications through additional processing.
- Until the mid-1990s, Teck Cominco[8] used to produce ammonium phosphate fertilizer at Trail (77,000 tonnes/yr.) and at Kimberly (87,000 tonnes/yr.), using imported phosphate rock from Montana.

Teck Cominco Smelter at Trail, BC

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## 1.3 Cominco Process

- Cominco developed the manufacturing technology for its phosphate fertilizers and still manufactures sulfuric acid.
- The process involved starting with about 900 tonnes of finely ground phosphate rock, which was treated with 800 tonnes of sulfuric acid, which liberated the phosphoric acid.
- The phosphate rock was then batched in a 300 $m^3$ stirred reactor, which produced the phosphoric acid and byproduct gypsum – fluoride, one of the constituents of phosphate rock, was produced as a byproduct and was used to make fluosilicic acid.
- Once concentrated, the phosphoric acid was clarified, ammoniated to produce a liquid ammonium phosphate, then dried and granulated to produce the finished fertilizer.[9]
- In 1986, the Kimberly complex (which included an iron sulfide roasting plant, a sulfuric acid plant, a rock crushing plant, phosphoric acid and fertilizer plant) was closed – during this time the Trail smelter underwent major modernization at a cost of over $1.0 billion (1977 – 1997).
- In 1993, the phosphate fertilizer production at Trail was transferred to Alberta when Teck Cominco's fertilizer operations were reorganized into a new company, Agrium Inc.[10]
- Currently, Teck Cominco produces zinc, lead, silver, gold, indium, germanium, bismuth, copper sulphate, copper arsenate, sulfuric acid, ammonium sulfate fertilizer, liquid sulfur dioxide, and elemental sulfur.[11]

**Bagging "Elephant Brand" Phosphate Fertilizer Trail, BC 1950's**

## 1.4 Agrium Inc.

- Agrium (based in Calgary) is one of the leading fertilizer producers in the world – sales have grown from $300 million to nearly $3.0 billion/y since the company was spun-off from Cominco in the early 1990's.[12]
- Agrium produces phosphate fertilizer in Redwater in Alberta (680,000 tonnes/yr.) and at Conda in Idaho (225,000 tonnes).
- Agrium has two phosphate mines – one at Rasmussen Ridge in Idaho and the other at Kapuskasing in Ontario, both produce 1.1 million tonnes/yr., with an average grade 38 percent $P_2O_5$ at each mine.
- High quality phosphate ore is mined in an open pit and processed into a fine powdered rock – the rock is added to water and sulphuric acid to produce a slurry of phosphoric acid and gypsum solids – the gypsum is filtered from the slurry, and the phosphoric acid is increasingly concentrated for various grades and uses.

**Agrium's 1.1 Million Tonne/yr. Phosphate Mine at Kapuskasing in Ontario**

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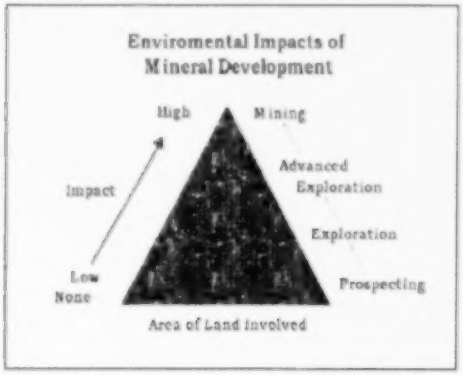
- A major input in the manufacture of phosphate fertilizer is sulphuric acid, which is also produced by Marsulex Inc. of Prince George, from byproduct sulfur (from natural gas processing in Northeast) – Endako Mines) also produces sulfurous acid (which is an intermediate product to sulfuric acid) as a byproduct of molybdenum roasting at the mine in Endako, northwest of Prince George.[13]

## 2.0 RESOURCE SENSITIVITIES

- The business of the mining industry is to supply the metals and minerals needed in our modern society – at the same time, mining companies want to conduct this business in an environmentally responsible manner.
- The nature of mining requires that land, air and water systems be temporarily disturbed – the challenge for companies is to find, extract and process mineral resources with the least possible disruption to these systems.




- Concern for the environment at Agrium's new phosphate mine near Kapuskasing Ontario is related to water usage, water quality and fisheries habitat – water from the tailings pond is used in the mill as reclaimed water – the mine is subject to continuous environmental monitoring and has a comprehensive reclamation plan is in place.
- When the Ontario phosphate mine closes, the pit will be flooded, creating a man-made basin of about 78 hectares – the pit edges will be re-sloped to provide a shallow littoral zone to assist in the development of fish population and improve slope stability – the completed lake will also provide a net increase in the amount of fisheries habitat over pre-development conditions.

### 2.1 Sensitivities

Some of the social, economic and environmental issues to be considered in establishing a phosphate mine include.

| Social | Economic | Environmental |
|---|---|---|
| ➤ Noise and vibration from blasting, crushing screening, back-up alarms<br>➤ Visual aesthetics.<br>➤ Dust from pit and trucks<br>➤ Heavy truck traffic safety and noise<br>➤ Site security and safety. | ➤ First Nations rights.<br>➤ Truck wear on roads serving the operation.<br>➤ Hours of operation. | ➤ Water use and discharges from surface erosion, product washing, and accidental spills.<br>➤ Groundwater impacts.<br>➤ Loss of plant cover and topsoil conservation.<br>➤ Fish and wildlife habitat impacts.<br>➤ Acid rock drainage. |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- Regarding fertilizer processing – for every tonne of phosphoric acid produced, five tons of phosphogypsum is generated – phosphogypsum can contain small amounts of sand, phosphate, fluorine, and other elements present in phosphate ore – this maybe an environmental concern requiring proper management.[14]
- Excess phosphorus runoff from agricultural lands contributes to eutrophication of water bodies (e.g., promotes weed growth, which decays depleting oxygen) – improved fertilizer management techniques can reduce phosphorus runoff.[15]

## 3.0 INVESTMENT REQUIREMENTS

- The phosphate rock used in the manufacture of phosphate fertilizer at Redwater in Alberta comes from phosphate mine near Kapuskasing in Ontario.
- The 1.1 million tonnes/yr Kapuskasing Mine cost about $100 million to develop which started production in 1999, is a high grade mine with reserves for at least 20 years, employing 120 in the open pit mine and mill.
- The Kapuskasing mine is the first major phosphate mine in Canada and ranks as one of the highest-grade phosphate mines in the world.

Agrium's Phosphate Nitrogen Operation – Redwater, Alberta

- A new sulfuric acid, phosphoric acid, and ammonium phosphate fertilizer plant would cost in excess of $400 million – most North American companies that produce phosphoric acid also mine and process their own rock.
- One of the major costs of producing phosphate fertilizer is for sulfuric acid – sulfuric acid costs from $60.00 to $100.00/tonne depending on location, quantities, and quality specifications.
- At most large phosphoric acid plants, including Agrium's Redwater, Alberta, plant, sulfur is burned to produce sulfuric acid – another major cost is for ammonia – Agrium is the one of the largest producers of ammonia and urea fertilizer in the world.[16]

## 4.0 INFRASTRUCTURE

### 4.1 Mining Infrastructure

- Regarding the open-pit mining operation: typical equipment includes excavators, loaders, haul trucks, crushers, screening and washing equipment, conveyor systems, stock pile areas, and loadout equipment for tucks, barges or ships.
- Operations require power, natural gas, diesel fuel, water, communications, and rail connections to ship the phosphate rock to Redwater, Alberta.


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### 4.2 Processing Infrastructure

- Agrium's 345,000-tonnes/yr.-phosphate fertilizer complex at Redwater, near Edmonton (as seen in the figure), is well serviced with rail infrastructure, in addition to roads, electricity, natural gas, water, etc.
- Transportation costs are a key consideration with respect to industrial products (e.g. high bulk to value), and whenever possible, established or low-cost transportation alternative must be utilized.

## 5.0 MARKETS

### 5.1 World Markets

- World phosphate rock production has declined from about of 149 million tonnes/yr. in the 1980's, to about 137 million tonnes/yr in the 1990's to 128 million tonnes/yr in 2001[17] – the US, Morocco, and Russia produce 70% of the world's phosphate rock.
- Sixteen companies including IMC Agrico, Cargill, CF Industries, Mississippi Chemical, produce the largest amounts of phosphate rock, primarily in Florida and North Carolina.[18]
- Canada's largest phosphate mine (Ontario's Kapuskasing mine), supplies 1.1 million tonne/yr. of phosphate rock to Canada's largest phosphate fertilizer complex at Redwater, near Edmonton.[19]
- Agrium also has a 1.5 million-tonnes/yr. phosphate rock mine at Rasmussen Ridge, Idaho, and a 482,000 tonnes/yr. $P_2O_5$ phosphate fertilizer plant at Conda, Idaho – Agrium has a large retail network in the US and sell farmers a complete package including seeds, chemicals and services.
- Although, the US supplies most of the phosphate fertilizers in the world, the US reported no exports of phosphate rock in 2002 – more than 50% of the phosphoric acid produced in the US is exported either as finished fertilizers or commercial acid.
- China and India have been the major importers of phosphate fertilizers, but a new plant in India has reduced import requirements –China is the largest fertilizer market in the world.

### 5.2 Quality Specifications

- At Ontario's Kapuskasing phosphate mine, ore occurs as unconsolidated or partially cemented material of sand sized crystals, crystal fragments and rounded grains – the phosphate ore varies in color from white through to tan, sandy brown, gray and dark gray to black.
- The average concentrated rock at the Kapuskasing Mine in Ontario and the Rasmusssen Ridge Mine in Idaho is a 38 percent ($P_2O_5$) – the mineral constituents in the run-of-mine phosphate rock from the Ontario mine is as follow [20]


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| Rock Constituent | Weight |
|---|---|
| | Percent Dry Basis |
| Phosphorus $P_2O_5$ (minimum) | 30 |
| Iron max | 10 |
| Moisture | 8-13 |
| Silica | 0-15 |
| Alumina | 0-5 |
| Magnesium oxide | 0-1 |
| Titanium oxide | 0-2 |

## 5.3 Prices

- Phosphate rock prices at the mine have increased from an average of $US 22.00/tonne in the 1980's, to $US 24.00/tonne in the 1990s to about $US 28.00/ tonne in 2001.[21]
- The Canadian wholesale price of phosphate fertilizer is about $200.00 per tonne.[22]

## 5.4 Future Market Trends[23]

- There are no substitutes for phosphate in fertilizers – over the next 20 years the world has to produce 40% more food crops on effectively the same land area.
- World demand for phosphate fertilizer will increase with population with the largest increased growth occurring in the developing nations.

# 6.0 EMPLOYMENT

- Agrium's Kapuskasing 1.1 million tonne/yr. phosphate mine in Ontario employs 130 people in the open pit and mill operation.
- A modern sulfuric acid plant, phosphoric acid plant and ammonium phosphate plant would employ about the same number of people.

| Mine and Fertilizer Plant | Workers |
|---|---|
| Phosphate Mine | 130 |
| Fertilizer and Acid Plant | 130 |
| Direct Employment | 260 |
| Indirect Employment (62 mine +114 plant) | 176 |
| Induced Employment (34 mine + 30 plant) | 64 |
| **Total Employment** | **500** |


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- With the addition of *indirect employment* (employment generated by the suppliers to the primary activity) and *induced employment* (employment created by the respending of employment income), the total employment is estimated to be about 500 jobs, based on the BC Input-Output Model employment coefficients.

## 7.0 RESOURCE CAPACITY

With a small population (4 million), relative to the large mineral-endowed landmass, BC is considered to be in an early stage of the development its mineral economy.

### 7.1 Southeast BC

- Several companies have explored the phosphate deposits in the extreme southeastern part of BC (which is noted more for its coal deposits) near Fernie, BC – Cominco Ltd. constructed adits at the Crow, Lizard and Marten properties in the 1950s – within an area of the Crow deposit phosphate was found with an average phosphate content of 26 percent.
- Metallurgical studies were also done on phosphate from the Line Creek area – tests showed acceptable concentrate grades could be produced with recoveries of about 75 percent – in 1982, First Nuclear Corp. Ltd. obtained phosphate grades in excess of 29 percent in the Cabin Creek area.[24]

### 7.2 Northeast BC

- Phosphate deposits in Northeast BC extend along relatively narrow, but long strip from Tumbler Ridge as to north of Fort Nelson (see map Appendix 1) – some of the known deposits are located within the Muskwa-Kechika protected area.
- In 1979, Esso Resources Canada Ltd. staked claims in the Wapiti Lake area west of Monkman Park, 60 km south of Tumbler Ridge – this deposit was mapped, test trenched and 12 sample holes were drilled in 1980 [25] – based on an average of 16 hand trenches and surface sections in 1988, a grade of 17 percent phosphate over 1.4 meters was found.[26]
- In 1998, a numbered company found phosphate rock beds varying in thickness from 0.8 to 3.2 meters with assays averaging 20 percent over one meter – the phosphate outcrops offers the potential for open pit mining with a low stripping ratio – there are several phosphate deposits near Tumbler Ridge, Chetwynd, and Fort Nelson.
- With the grades so far found, BC phosphate rock will require additional processing (e.g., beneficiation) to raise the phosphate levels to commercial standards of 38 percent $P_2O_5$.
- Trials done by Cominco and Natural Resources Canada did not yield sufficient quality, but new technology may offer opportunities for achieving better results – processes developed in the US for ores similar to the BC grades have achieved commercial grades with acceptable recoveries.[27]


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# 8.0 REGULATION

## 8.1 Provincial Approvals

- The *Environmental Assessment Act* established BC's environmental review process, coordinated by the Environmental Assessment Office, which reviews the potential environmental, social, economic, cultural, and heritage impacts of large-scale development projects.
- Reviewable projects include metal, mineral coal and placer mines, aggregate operations (i.e. sand, gravel,) and industrial quarries (e.g., crushed rock, dimension stone), offshore mines, in addition to related processing of primary metals, minerals and mineral products and manufacturing (cement, glass, lime and asbestos).
- The BC environmental review process accommodates simultaneous review of the required permits and licences – application of permits and licences may need to incorporate detailed engineering design information, which may be difficult to justify without first approving approval-in-principle through environmental assessment approval.
- Provincial statues and regulations[28] that may apply to aggregate operations, include: the *Mines Act* (Health, Safety and Reclamation Code), *Forest Land Reserve Act*, *Forest Act*, *Range Act*, *Forest Practices Code Act*, *Soil Conservation Act*, *Agricultural Land Reserve Act*, *Land Act*, *Highway Act*, *Water Act*, *Heritage Conservation Act*, *Environmental Assessment Act*, *Fish Protection Act*, *Waste Management Act*, *Wildlife Act*.
- Most industrial mineral produced in BC is from private land – production from Crown land requires leases to be obtained under the *Land Act*.
- Industrial mineral quarries are regulated under the *Mines Act* and mining permits include requirements for securities to ensure reclamation – minerals produced from Crown land are subject to a mineral tax under the *Mineral Tenure Act*.
- Provincial standards required under the *Waste Management Act* for particulate and sulfur emissions from limekilns are also very important.

## 8.2 Federal Approvals

- When a large-scale project triggers the *Canadian Environmental Assessment Act*, the BC and Federal governments have agreed to co-operate in a joint review process – at the end of a Federal-Provincial review, each government makes a separate decision on the project.
- Federal involvement can be triggered when projects require interprovincial or international or otherwise federal approvals, which receive federal financial assistance, or involve federal lands.
- Federal statues and regulations[29] that may apply, include: the *Fisheries Act*, *Canadian Environmental Assessment Act* (projects >1 million tonnes/yr.), the *Navigable Waters Protection Act*, *Canadian Environmental Protection Act*, *Migratory Birds Convention Act*, *Canada Wildlife Act*.


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### 8.3 Local Approvals

- Local government regulate operations on private land through application of local bylaws that can affect emissions, soil removal, hours of operation, noise, truck transport routes, and other operating conditions (e.g., the Greater Vancouver Regional District Air Pollution Control bylaw regulating fuel use and discharges from cement kilns).
- The Minister of Municipal Affairs and the Minister of Energy and Mines approve municipal bylaws that affect mineral extraction – while mineral extraction is not a land use subject to zoning, municipal bylaws and zoning can apply operating restrictions - limitations on the duration of an aggregate lease can affect decisions related to investments in processing equipment.
- Local bylaws[30] and other requirements that may apply at the local level, include: the *Local Government Act*, *Soil Conservation Act*, *Growth Strategies Act*, Memorandums of Agreement, Official Community Plans, Bylaws, Soil Removal Bylaws, Zoning, Subdivision & Servicing Development, Noise by-laws, Tree Retention, Commercial Vehicles, Business Licenses.

### 8.4 Approval Lead Time

- Timelines for the government portion of BC environmental assessment review is set out in regulation – the length of the review process depends on the complexity of the issues and could range from 12 to 30 months, or longer if a public hearing is required.

## 9.0 GOVERNMENT REVENUES

- The value-added processing industrial minerals in BC, generates additional, employment and corporate income tax, sales and fuel taxes tax, beyond that from the mining and extraction of the minerals.
- The following table lists the various local, provincial and federal taxes and levies related to the production and transportation of industrial minerals in BC.

**Municipal**
Business License Fees
Property Taxes
Soil Removal Fees
**Provincial**
Employee Income Taxes (81k/worker, 7%)
Crown Lands- Land Rent Fee
Provincial Sales Tax (7.5%)
Corporate Income Tax- (13.5%)
WCB (0.33% wage rate)
Fuel tax


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| Federal |
|---|
| Employee income taxes (81k/worker, 14%) |
| Employment Insurance (3.15%) |
| Corporate income taxes (26.12%) |
| Goods and Service Tax (7.0% on margin) |
| Federal Excise Tax on fuel |

# 10.0 INPUT-OUTPUT COEFFICIENTS

## 10.1 Demand Coefficients

- Since most industrial minerals are intermediate inputs (used in the production of other industrial products), it can be difficult to relate the demand for an industrial mineral to an end-use demand factor, such as population, construction starts, etc.

## 10.2 Employment Coefficients [31]

- The BC Input-Output Model provides employment coefficients for some of the major components of the BC industrial mineral industry.
- As shown below, the direct employment for a phosphate mine (i.e., non-metal mines, except coal) is estimated to be 7.85 jobs per $1,000,000 in revenues and for chemical chemicals (fertilizer plant) is 3.26 jobs per $1,000,000 in revenues.

| Employment/million sales /yr at pit | Direct | Indirect | Induced | Total |
|---|---|---|---|---|
| Non-Metallic Mines | 7.85 | 3.73 | 2.03 | 13.61 |
| Agricultural Chemicals | 3.26 | 2.88 | 0.74 | 6.88 |

- Direct Employment – is the employment associated with the direct activity.
- Indirect Employment – is the employment generated within the BC economy from suppliers of the goods and services required to produce the primary product.
- Induced Employment – is generated from the suppliers paying out wages to their employees, which are then respent in the economy (net of savings and taxes).
- Total Employment - is the sum of this total economic activity, (i.e., direct and spin-off impacts) composed of three components (direct, indirect and induced).

## 10.3 Labor and Capital Intensity

- The employment coefficients above reflect the relative labor intensity of the industrial mineral activity – low labor intensity generally reflects a higher capital intensity in an industry, and higher labor productivity per worker.


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- Firms attempt to equalize the productivity from both capital and labor, which allows them to stay competitive and sustain operations (e.g., protect employment) during the ups and down of commodity price cycle.

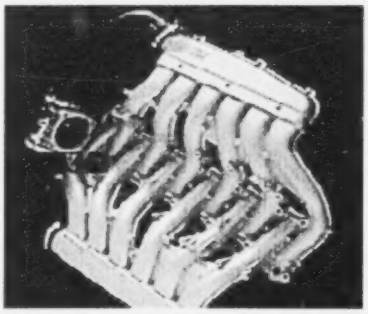
# MAGNESIUM METAL

## 1.0 OVERVIEW

### 1.1 Introduction

- Uses: – Magnesium is non-toxic, non-magnetic, and is widely used in transportation (motor vehicles, aerospace, and rail transport), packaging (beverage cans, aluminum packaging), construction, consumer durable goods, machinery and equipment, electrical applications, laptop computers, mobile phones, power tools, fireworks, optical mirrors; pyrotechnics, military illumination, machinery, television sets, military armaments, tracer bullets, etc.
- Weight: – Lightest of all structural metals, 75 percent lighter than steel and 33 percent lighter than aluminum (magnesium density 1,738 kg. /$m^3$ versus 2,700 kg. /$m^3$ for aluminum)

Example of Intricate Magnesium Die Casting



- Strength: – Has exceptional strength to weight ratio for load bearing parts versus steel and aluminum
- Die casting Qualities: – Molten magnesium's low viscosity makes for improved die-casting for larger more complex components.
- Vibration: – Excellent ability to absorb energy vibration, act as a dampener and highly dent resistant.
- Environment: lightweight magnesium parts are the key to reducing vehicle weight and therefore improving vehicle fuel efficiency and reducing greenhouse gas emissions.
- About half of the magnesium produced is used to make alloys of aluminum for beverage cans beverage cans – without the high level magnesium in the lid, the lid could not be opened (an aluminum can is typically 1.5 percent Mg and the top is 4.5 percent Mg)

### 1.2 Electrolytic Process

- Magnesium is a reactive metal and is usually found in nature in the form of an oxide, carbonate or silica, often in the presence of calcium – this reactivity is one reason the production of magnesium metal requires large amounts of energy.
- A BC plant would likely use the common electrolytical process to produce magnesium metal from magnesium chloride by reacting magnesium hydroxide with hydrochloric acid or chlorine.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- Lime is added to precipitate the magnesium hydroxide – the hydroxide is filtered and treated with acid to form magnesium chloride[32] – the magnesium chloride is then purified, dried then processed in electrolysis cells – it is heated to a molten state and chlorine is separated leaving magnesium metal floating on the spent electrolyte – the magnesium is then can cast into ingots or alloys.
- Magcorp of Salt Lake, Utah and Norske Hydro in Becancour in Quebec uses dry magnesium chloride for their electrolytic cells – Norsk Hydro, Noranda, VAMI (Russian National Aluminum and Magnesium Institute), and UTI (Ukrainian Titanium Institute) are among the leaders in the electrolytic technology.
- Magnesium production in the Ukraine, and Kazakstan uses either natural or manufactured magnesium and potassium chloride, called carnallite (i.e., $MgCl_2 \bullet KCl \bullet 6H_20$) – potash and magnesium salt beds are dissolved to form a brine – the brine is evaporated to form potassium chloride and magnesium chloride salts – the byproducts of this process, include about 4 tonnes of potash and 3 tonnes of chlorine for each tonne of magnesium metal.

## 1.3 Canadian Producers

- In 2000 Noranda built the Magnola magnesium plant in Danville Quebec, at a cost of $900 million, which is 20 percent owned by the Quebec government and Noranda – the plant will use serpentine tailings as its raw material.[33]

Noranda's New Magnola Magnesium Plant : Quebec

- The Magnola plant is expected to have a production capacity of 60,000 tonnes/yr. or close to 20% of world supply, and has created 315 employees – the plant's raw material source is a pre-existing 300-year supply of serpentine tailings which contain about 24 percent magnesium, located adjacent to the plant site.
- Hydro Magnesium Canada (Norske Hydro) has a 48,000-tonne/yr. magnesium plant at Becancour, Quebec, which started production in 1989 – the plant has 370 employees producing magnesium production, using some recycled metal.
- Timminco has a small magnesium plant in Haley, Ontario, which is located approximately 100 kilometres west of Ottawa, Ontario – the plant is a fully integrated magnesium facility, incorporating a dolomitic limestone deposit and facilities for calcination, feed preparation, reduction, refining, and casting of ingots and billets.


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## 1.4 BC Projects

➤ Two magnesium metal projects are currently proposed for BC.

| Company | Proposal | Location | Process |
|---|---|---|---|
| Cassiar Resources Ltd.,[34] Vancouver, BC | Asbestos tailings leach plant 90,000 tonne/yr. smelter | Northwest BC, tidewater, | Similar to Noranda process at Danville, Quebec |
| Leader Mining Int'l Inc.,[35] Vancouver, BC | Open pit magnesium silicate mine 120,000 tonne/yr smelter | Near Hope, 20 km northwest. | Russian electrolytic technology |

➤ The Cassiar project would use technology similar to that used by Noranda using asbestos tailings[36] – asbestos tailings contain about 40 percent magnesium oxide, 38 percent silica, 5 percent iron compounds and 13 percent water.

➤ The tailings are continuously leached by a hydrochloric acid solution – the base metal impurities are separated and the solution is sparged (e.g., sprayed) with chlorine gas and fed through ion exchange columns to remove traces of metal impurities – the purified magnesium chloride brine is dried and then electrolyzed in Alcan cells.

## 1.5 Thermal Process

➤ Another magnesium manufacturing technology is thermal reduction of dolomite or magnesite.[37]

➤ Many small plants, such as the Timminco plant at Haley in Ontario and most plants in China use thermal processes – natural gas or electricity is used to heat magnesium oxide so that it react it with the ferrosilicon to produce magnesium vapor, which is cooled and condensed.

➤ Bagmag Mines, near Radium Hot Springs produces about 200,000 tonnes/yr. of magnesite (magnesium carbonate), which it is transported it to Exshaw, Alberta for processing to magnesium oxide and used to produce refractory and other chemicals.

➤ A company called Magcan built a plant in High River in Alberta, to convert Baymag's magnesium oxide from Exshaw to magnesium metal, but the high temperature electrical process did not work as expected and the plant closed in 1991.[38]

# 2.0 RESOURCE SENSITIVITIES

## 2.1 Mining

➤ Regarding the leaching of asbestos tailings or magnesium silicates with hydrochloric acid– this process would require careful control of wastewater and to design the process to eliminate any possibility of accidental spills

➤ The social, economic and environmental issues to be considered in establishing a magnesium mine would be similar to other mines (refer back to Section 2.0 Phosphates).


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### 2.2 Processing

- Electrolytic magnesium smelting involves environmental challenges similar to those at an aluminum smelter (Kitimat) and lead and zinc smelting (Trail).
- Disposal of byproduct salts and sludge, air emissions and chlorine gases are among some of the key waste management issues to be addressed –sulfur hexafluoride, which is used to protect molten magnesium from oxidation) is a greenhouse gas.
- The remaining US magnesium plant, located at Salt Lake in Utah, announced that it was installing new cell technology that would reduce emissions.

## 3.0 INVESTMENT REQUIREMENTS

- A magnesium plant in BC would require low cost energy (e.g., the Noranda magnesium plant in Quebec receives low cost electricity)

### 3.1 Capital Requirements

Typical capital requirements of current magnesium projects are identified below.

| Company | Location | Size | Cost | Source |
|---|---|---|---|---|
| | | (tonnes/yr.) | ($US) | (of Mg) |
| **Operating Plants** | | | | |
| Dead Sea Magnesium | Israel | 30,000 | 420 | Seawater |
| Magnola, Noranda | Quebec | 63,000 | 733 | Asbestos Tailings |
| **Proposed Plants** | | | | |
| Magnesium Alloy | Congo | 60,000 | 514 | Solution Mine |
| Australian Magnesium Corp | Queensland | 90,000 | 520 | Magnesite |
| Leader Mining | BC | 120,000 | 616 | Magnesium Silicate |
| Cassiar Resources | BC | 90,000 | 600-900 | Asbestos Tailings |

## 4.0 INFRASTRUCTURE

### 4.1 Mining Infrastructure

- A new mine would require an all weather road, power, water, utilities and a source of labor, water, communications, and close proximity to or good road connections to the processing plant.
- The project at Cassiar, although remote and not integrated to the provincial power grid, was a former mine and would have some infrastructure.


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- Regarding mining operation – typical equipment includes excavators, loaders, haul trucks, crushers, screening and washing equipment, conveyor systems, stockpile areas, and loadout equipment.

### 4.2 Processing Infrastructure

- Similar to aluminum, the production of magnesium metal is energy intensive; therefore the key to project feasibility is access to a large source of low cost electricity – in addition to road, rail, port access and all other utilities.
- Competitive suppliers producing magnesium metal, such as Hydro Magnesium Canada (Norske Hydro) plant at Becancour, QC, obtains power at about - $0.01/kW.h – the Magnesium Alloy Corp.'s project in the Congo, a 60,000 tonnes/yr. project obtains 120 MW at $0.016/kW.h [39]

## 5.0 MARKETS

### 5.1 Market Statistics [40]

- Compared to other structural metals the world magnesium metal market is relatively small at about 500,000 tonnes in 2002, with an expected growth rate of 6 percent per year.[41]
- The consumption of magnesium metal in the US is as follows: – transportation 35 percent; beverage containers, 24 percent, iron and steel desulphurization 13 percent; machinery 12 percent; nodular iron and other uses 16 percent.
- Recycled magnesium, especially from aluminum cans makes up 42 percent of the US supply – more than 60 percent of beverage cans are recycled.
- Automakers are producing lighter, more fuel-efficient cars using magnesium in die cast components such as wheels, brake and clutch petal brackets, instrument panels, cylindrical head covers, transfer case housings, intake manifolds, and seat components – research is proceeding on magnesium alloy engine blocks (major weight/fuel savings) – the average magnesium content is 4.1 kilograms per car in 2002.

### 5.2 Buyer Involvement [42]

- Companies proposing new magnesium plants are obtaining long-term purchase agreements or other financial commitments from major magnesium metal users, such as major automobile manufacturers.
- Volkswagen AG invested $100 million in the Dead Sea Magnesium plant in Israel for a 35 percent interest and is expected to consume 10,000 tonnes/yr. of the plant's magnesium output.
- Ford Motor Co. has invested $30 million in a pilot plant by the Australian Magnesium Co.(Queensland) and has placed an order for magnesium metal.
- General Motors has a long term supply agreement with Norske Hydro In Quebec, for their Becancour magnesium plant.


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➤ The Aisin Group (a parts supplier to Toyota) is a joint venture partner in Noranda's new Magnola project in Quebec.

## 5.3 Suppliers[43,44]

➤ The two Canadian magnesium plants in Quebec are the largest in the world – the next largest magnesium plants are in Russia, Kazakhstan and the Ukraine – the Australians are adding additional capacity.

| Company | Location | Capacity |
|---|---|---|
| | | (tonnes/yr.) |
| Norske Hydro | Becancour, Quebec | 48,000 |
| Magnola (Noranda) | Danville, Quebec | 63,000 |
| Avisma | Russia | 55,000 |
| Ust-Kaminogorsk | Kazakhstan | 50,000 |
| Zaporzhye Titanium & Magnesium Co. | Ukraine | 45,000 |
| Magnesium Corp of America (Renco) | Salt Lake, UT US | 43,000 |
| Dead Sea Magnesium | Israel | 30,000 |
| Solikamsk Magnesium | Russia | 20,000 |
| Kalush | Ukraine | 15,000 |
| Jilin Linjiang Mag Industry Group | China | 15,000 |
| Taiyuan Yiwei Magnesium | China | 15,000 |
| Taiyan Tongxiang Magnesium | China | 14,000 |
| Wenxi Yingguang Magnesium | China | 12,000 |
| RIMA | Brazil | 12,000 |
| Shanxi Yiwei Magnesium Co. | China | 10,000 |
| Shanxi Tongxiang Mag Co. | China | 10,000 |
| Tongbao Magnesium | China | 10,000 |
| Rima Industrial S/A (Brasmag) | Brazil | 9,000 |
| Gold River Magnesium | China | 9,000 |
| Guangling Chemical Co. | China | 8,000 |
| Huayuan Shizuizhan Magnesium | China | 8,000 |
| Minhe Magnesium Co. (Electrolytic) | China | 7,000 |
| Timminco Metal | Haley, Ontario | 7,000 |
| Preussag | Iceland | 7,000 |
| Huanqi Magnesium Industry | China | 6,000 |
| Fushun Magnesium Co. | China | 5,000 |
| Taiyuan Luowei Oriental Magnesium | China | 5,000 |
| Magnohrom | Serbia | 5,000 |
| Southern Magnesium & Chemicals | India | 1,000 |
| **Total** | | **544,000** |

Excludes recycled magnesium.

## 5.4 Quality and Prices[45]

➤ In recent years, there has been a steadily decline in magnesium prices from $US2.25/lb. in 1995 to about $US1.30/lb. in 2001.[46]

➤ Low priced Chinese and Russian imports have contributed to the closure of some plants in the West, including Norsk Hydro's, 60,000-tonnes/yr. smelter in Porsgrunn, Norway in


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2002, and Pechiney's, 16,000-tonnes/yr smelter in France, and the Dow Magnesium plant in Texas in 1998.[47]

- Prices range from a low $US0.90/lb. ($2,000/tonne) from some of the small Chinese plants to $US1.30/lb ($2,900/tonne) from the Quebec plants.[48]
- Chinese exports of magnesium may not be sustainable, due to antidumping measures, uneconomic prices, and increased environmental regulations – the smaller plants are expected to shutdown first.
- Lower prices will contribute to more widespread use of magnesium metal, but also inhibits investment in new plants – overall demand for magnesium in the automobile sector is expected to grow at 11 percent worldwide to 2005.
- Magnesium prices are forecast to fall below $2,000/tonne by 2004 because new larger lower cost plants are coming on line.[49]

## 6.0 EMPLOYMENT

- Noranda's Magnola Plant in Danville Quebec plant could be similar in size to a smelter in BC and has 315 employees, including the tailings mining operation.[50]
- There are trained employees in the Northwest BC and in the Vancouver area capable of working in a magnesium smelter – some of the best commercial expertise for these projects can be obtained from companies based in Quebec.

| Mine and Magnesium Metal Plant | Workers |
|---|---|
| Tailings Mining Operation | 100 |
| Magnesium Metal Plant | 215 |
| Direct Employment | 315 |
| Indirect Employment (48 mine +216 plant) | 264 |
| Induced Employment (26 mine + 82 plant) | 108 |
| **Total Employment** | **687** |

- With the addition of *indirect employment* (employment generated by the suppliers to the primary activity) and *induced employment* (employment created by the respending of employment income), the total employment is estimated to be about 687 jobs, based on the BC Input-Output Model employment coefficients.

## 7.0 RESOURCE CAPACITY

- Magnesium is the 6th most abundant elemental metal on earth, however it high chemical reactivity means its not found in its metallic state.
- Magnesium must be obtained from dolomite, magnesite and carnallite, in addition it can be produced from lower concentrations sources, such from seawater, groundwater brines and surface salt deposits (e.g., the Great Salt Lake).[51]


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| Source | Formula | Magnesium |
|---|---|---|
| | | (Percent) |
| Sea Water | MgCl2••MgSO4 | 0.14% |
| Lake Brine | MgCl2••MgSO4 | 0.80% |
| Carnallite | MgCl•KCl•6H2O | 8.80% |
| Dolomite | MgCO3•CaCO3 | 13.20% |
| Serpentine | 3MgO•2SiO2•2H20 | 26.40% |
| Magnesite | MgCO3 | 28.83% |

- BC sources include the 80,000-tones/yr. Baymag magnesite mine (Mount Brussilof) near Radium Hotsprings, which is used to produce magnesium oxide for refractory products.
- BC has several sources from which magnesium metal can be produced – the feasibility to produce magnesium metal is more sensitive to processing costs, rather than the availability of raw material.
- The comparative advantage of the Chinese capacity is low cost labor and low environmental standards – the comparative advantage of the Quebec magnesium metal capacity is low cost electricity.

## 8.0 REGULATION

- Regulations that apply to the Quebec and Utah smelters would likely be relevant for a new BC magnesium smelter.
- A project involving a new mine, acid leaching technology, as well as a smelter and would be more complex and would require extensive social, economic and environmental studies.
- See section 7.0 Phosphates.

## 9.0 GOVERNMENT REVENUES

- Industrial mineral and smelting businesses are subject to fees and taxes, similar to other businesses – the value-added processing of minerals in BC, generates additional downstream employment and corporate income tax, sales and fuel taxes tax, beyond that from the mining and extraction of the minerals alone.
- The production of magnesium metal in BC could generate additional aluminum-magnesium alloy business opportunities (e.g., Alcan, Ballard fuel cells, etc.).
- Some of the fees and taxes that would apply to the magnesium silicate mine and magnesium smelter include:[52]


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**Municipal**
- Business License Fees
- Property Taxes
- Soil Removal Fees

**Provincial**
- Employee Income Taxes (81k/worker, 7%)
- Crown Lands- Land Rent Fee
- Provincial Sales Tax (7.5%)
- Corporate Income Tax- (13.5%)
- WCB (0.33% wage rate)
- Fuel tax

**Federal**
- Employee income taxes (81k/worker, 14%)
- Employment Insurance (3.15%)
- Corporate income taxes (26.12%)
- Goods and Service Tax (7.0% on margin)
- Federal Excise Tax on fuel

# 10.0 INPUT-OUTPUT COEFFICIENTS

## 10.1 Demand Coefficients

- With concern over air quality and climate change, the expanded use and application of magnesium metal is expected in many transportation applications.

## 10.2 Employment Coefficients[53]

- The BC Input-Output Model provides employment coefficients for non-ferrous metal smelting and refining industry in the BC (e.g., lead, zinc and aluminum).
- As shown below, the direct employment for a new magnesite mine (i.e., non-metal mines, except coal) is estimated to be 7.85 jobs per $1,000,000 in revenues and for 2.55 jobs per $1,000,000 in revenues for a new smelter in BC.

| Employment/million sales /yr at pit | Direct | Indirect | Induced | Total |
|---|---|---|---|---|
| Other Non-Metal Mines (Except Coal) | 7.85 | 3.73 | 2.03 | 13.61 |
| Non-Ferrous Metal Smelting and Refining | 2.55 | 2.56 | 0.97 | 6.08 |

- Direct Employment – is the employment associated with the direct activity.
- Indirect Employment – is the employment generated within the BC economy from suppliers of the goods and services required to produce the primary product.
- Induced Employment – is generated from the suppliers paying out wages to their employees, which are then respent in the economy (net of savings and taxes).


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- Total Employment – is the sum of this total economic activity, (i.e., direct and spin-off impacts) composed of three components (direct, indirect and induced).

### 10.3 Labor and Capital Intensity

- The employment coefficients above reflect the relative labor intensity of the industrial mineral activity – low labor intensity generally reflects a higher capital intensity in an industry, and higher labor productivity per worker.
- Firms attempt to equalize the productivity from both capital and labor, which allows them to stay competitive and sustain operations (e.g., protect employment) during the ups and down of commodity price cycle.

# DIAMONDS

## 1.0 OVERVIEW

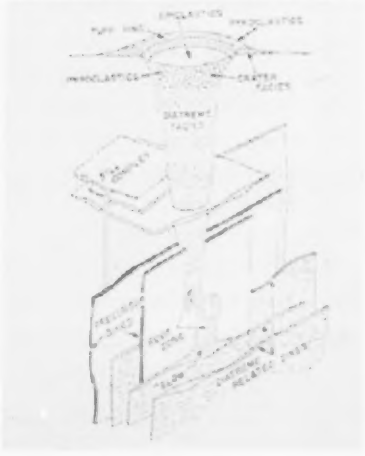
### 1.1 Introduction

- Most diamonds probably formed relatively soon after the formation of the Earth – Canada's diamonds formed under archons, which are thick and stable parts of the crust that are 2.5 billion years old, at a depth of at least 200 km. – diamonds form from crystallized carbon at a particular balance of high pressure (about 5,800,000 psi) and high temperature (from 1,100°C to 1,482°C).[54]
- Diamonds are found in two types of geological rock formation, kimberlites (carrot shaped) and lamproites (champagne glass shaped), of these only kimberlites are likely to be found in Canada.

### 1.2 Kimberlite Pipes

- Wherever kimberlite eruptions have occurred, they have done so in clusters – the magma moves under pressure toward the surface and where there were weaknesses in the crust near the surface, the force of the kimberlite magma's final push typically blasts a path, called a pipe, that is shaped like a funnel with the widest part at the surface – kimberlite pipes extend hundreds of metres below the current surface.
- As the magma approaches the surface its temperature and the pressure decreases and if this happens too slowly, the diamonds in the kimberlite are dissolved – less than one per cent of all kimberlite pipes have diamonds.

Carrot Shape of a Kimberlite Pipe

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- Canada has one producing diamond mine, the Ekati mine in the Northwest Territories (NWT), located 320 km. Northeast of Yellowknife, which began commercial operation in October, 1998 – a 2nd mine, the Diavik diamond mine in the NWT, is expected to start in 2003 – the Ekati and Diavik operations are mining kimberlite pipes.
- Diamonds are also found in alluvial deposits where the kimberlite pipes and dykes have been eroded by glaciation, wind and rain and deposited along the surface, often along the river courses – the diamond regions along the west coast Namibia in Africa are one the most famous examples of this type of alluvial diamond deposit.
- Currently the centres of exploration for diamonds in Canada are the NWT, Nunavut, the Otish Mountains in Quebec, the Fort a La Corne area in Saskatchewan and the James Bay Lowlands in Ontario.
- Kimberlite occurrences have been discovered in BC and these pipes have been partially explored and found to contain macro-diamonds (i.e., larger than 0.5 mm).

## 1.3 Scale of Operation

- Diamond mine and processing plants, vary from the Argyle Diamond Mine (Australia) treating approximately 12 Mt/yr. to small-containerised diamond placer operations.
- For the purposes of this Building Block a 10,000-tonnes/day ore plant to produce industrial and gem quality diamonds is discussed, with an assumed site being in the western ranges of the Rocky Mountains in close proximity to infrastructure.
- The mine is assumed to be based on a grade of 50 carats per 100 tonnes of ore, so the mine would produce 5,000 carats/day of industrial and gem quality diamonds[55]

## 1.4 Mine Development

- Mine development typically involves five major phases: (1) – Exploration and Development, including permitting and environmental studies (5 to 10 years), (2) – Mine Construction (1 to 3 years), (3) – Mine Operation (10 years), (4) – Closure (2 years), and (5) Site Rehabilitation (4 years).

## 1.5 Exploration and Development

- Exploration typically involves remote geophysical techniques (e.g., satellite images, airborne gravimetric surveys, geological mapping, IP surveys), which can identify high potential targets.
- Land-based activities include diamond drilling, geochemistry, exploration adits (tunnels), trenching and sampling, assaying – these activities yield information to justify further development expenditures, normally supported by a pre-feasibility study.
- Detailed exploration then proceeds to develop sufficient confidence to support a project development decision – this requires further diamond drilling, bulk samples, metallurgical testing, pilot plant work and the preparation of a final feasibility study to justify the project financing decision.
- Permitting – Environmental baseline studies start during the exploration stage, continue through the design stages – permitting usually takes several years.


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### 1.6 Design and Construction

- This step involves detail design and construction of the mine – construction involves – access improvement, site preparation, engineering, procurement, transport of equipment and materials to site, construction, commissioning and start-up.

### 1.7 Operation

- Open pit mining of a diamond bearing kimberlite pipe involves transporting ore to the crushing plant, primary and secondary crushing, wet scrubbing and screening, high pressure crushing, secondary scrubbing and screening, heavy media separation, wet and dry high intensity magnetic separation, x-ray sorting, acid wash cleaning of stones, hand sorting, cutting and polishing, water supply and disposal of waste rock and disposal of fines to a tailings impoundment, water management, environmental monitoring, inspection, including, water quality, (crushed kimberlite sediment settlement), air quality and fish and wildlife management.
- The process will be designed to recover diamonds in the smaller than 25 mm to greater than 1 mm size range – the plant would be designed to be highly automated, to minimize labor requirements and keep the process "hands-off" – helping to reduce the risk of theft.
- The "carrot shape" and small scale of the kimberlite pipes requires that other pipes or dykes in the vicinity be mined as the initial pipes are depleted – ongoing capital expenditures to bring other pipes into production may be capital intensive depending upon the location of the new pipes relative to the processing plant.
- During operation the mine supports a wide range of suppliers, including electricity and utility suppliers, camp management, food, fuel, transportation, access road maintenance that helps others forestry, recreational, prospectors, equipment suppliers, communications etc.

### 1.8 Closure and Reclamation

- Following an assumed 10-year operating life, the next phase is preparation for closure, plant resale/relocation, demolition and site rehabilitation.
- The objective of rehabilitation is to return the site to an equal or better land use, and will include, pit or mine stabilization, tailings impoundment reclamation – reclamation bonds, are required to be put in place by mining companies to ensure rehabilitation is completed.

## 2.0 RESOURCE SENSITIVITIES

- The social, economic and environmental issues to be considered in establishing a diamond mine would be similar to other mines (refer back to Section 2.0 Phosphates).
- Mining operations represent a temporary land use – when operations are completed, reclamation can restore the land to its earlier condition and in some cases create higher-valued land uses, such as improved wildlife habitat.


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# 3.0 INVESTMENT REQUIREMENTS

- Investment requirements can be broken down into the five developmental stages, exploration and development (including permitting), mine and processing plant design and construction, operation, closure, rehabilitation.
- Estimated investment requirements by each of the mine life-cycles based on a 10 year mine life, are shown below[56]:

| Development Phase | Open Pit Diamond Mine |
|---|---|
| Product (Industrial and Gem Diamonds) | Diamonds |
| Processing Capacity (tonnes of ore/day) | 10,000 |
| Operating Employment | 400 |
| Exploration and Development ($C M) | 27 |
| Design and Construction ($C M) | 305 |
| Operating Costs ($C M tonne milled) | 24 |
| Offsite Handling and Shipping Costs | 5 (Incl. Security)/year |
| Summary Ongoing Capital Costs ($C M) | 50 |
| Closure Costs ($C M) | 10 |
| Rehabilitation Costs ($C M) | 20 |

# 4.0 INFRASTRUCTURE

## 4.1 Open Pit Diamond Mine

- Infrastructure would normally include access roads and power supply, tailings disposal facility, waste rock dumps and ancillary facilities, such as camps, security buildings and systems, truckshop, warehouses, repair shops and offices.
- A typical mine in this class could have all weather road access perhaps 20 km from the provincial road system - these roads would be used for the transportation of bulky equipment, materials and consumables for both construction and operation – diamonds or diamond concentrate would be shipped by air on an irregular basis.
- The mine will be connected via a 20km overhead power line from the provincial grid – water will be sourced from local wells, lakes and rivers.
- It is assumed that the mine is in the vicinity of an existing town, and that personnel for the operation will commute daily to the mine – training of personnel will be required to ensure that the workforce is skilled for the operation of this highly automated process plant.
- Rough diamonds or a diamond concentrate will be transported by air, most likely to a further processing/sorting facility, probably in Yellowknife or Vancouver.


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# 5.0 MARKETS

## 5.1 Marketing[57]

- **Production** – the product of the example diamond mine are industrial and gem quality rough diamonds – world diamond production of natural rough diamonds in 2000 was at 100.7 million carats valued at $US 7.8 billion, for an average price of $US71.00/ct.[58] – Ekati production in the NWT is about 2.5 million carats a year with an average price of $US160.00 per carat, one of the highest prices in the world.[59]
- **Grade** – grade is the weight of diamonds expressed as carats per tonne (ct/tonne) or carats per hundred tonnes, and varies widely from one mine to another, but generally is between 0.3 and 1.3 ct/tonne – the value of the ore per tonne equals the grade times the value per carat of all the individual recoverable diamonds in the deposit.
- **Size (Weight)** – the average size of rough diamonds can vary from 0.01 ct (about 1mm in size) to more than 0.7 ct – many mines average about 0.4 to 0.5 ct per stone – stones larger than 1 ct account for only 0.5% of world production.
- **Mine Production Costs** – production costs vary widely from $US 5.00 /tonne for large easy to access mines in good climates to $US 35.00-38.00 /tonne for small mines in harsh climatic conditions – the total production costs for these mines are in the order of $US 15.00 /tonne and $US 45.00 /tonne, respectively.
- **Prices** – there are no international set prices for diamonds – market prices for rough natural diamonds are constantly in a state of flux.
  - Industrial Quality Diamonds[60] – crushing bort US$0.30/ct; industrial stones US$7.00-10.00/ct; and dies (large diamonds of poor colour) $US200.00/ct.
  - Gem Quality Rough Diamonds – price depends on carat weight, shape, clarity and colour, for a 1 carat rough stone prices per carat can vary as follows: – very low quality $US20.00, $US 200.00 for medium quality, $US400.00 for good quality and $US1,000.00 for top quality.
- Polished Diamond Industry – each year more diamonds are being sold outside of the De Beer's Diamond Trading Company [61] and there has been a movement towards separately branding specific diamond product with purity or high quality of colour, clarity and cut – BHP Billiton Diamonds is a good example of this with its Canadian Ekati diamond marketing program.
- "Conflict-Free" Diamonds – Canadian Ekati diamonds are marketed on the basis that they are conflict free – "conflict diamonds" refers to those diamonds that are used by various rebel movements to finance conflict aimed at undermining legitimate governments, as described in relevant UN Security Council resolutions.

## 5.2 Market Exports

- New diamond developers would likely enter into agreements with diamond cutting and polishing companies for the supply of diamonds prior to finalising construction details – the cutting and polishing companies could be in Yellowknife, or in any other centre for cutting and polishing diamonds, such as Antwerp, Belgium, Tel Aviv, Israel or Mumbai, India.


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### 5.3 Value and Production

- Based on the estimated grade of 50 carats per 100 tonnes the example mine would yield 5,000 carats per day - the anticipated quality and price of the rough diamonds is not known.
- Typical values from a selection of African, Australian and Canadian diamond sites are given below:
  - Argyle $US 10.00/carat
  - Jwaneng $US 100.00 /carat
  - Venetia $US 100.00/carat
  - Ekati $US 160.00 /carat
- Using the global average value of $US 71.00/ct as a reference price, the diamond production would have a value of $US $355,000 /day, equivalent to $US 124.0 million/yr. 350 days /yr. operation.
- Operating costs are estimated while taking into account the higher labour costs and plant modifications to accommodate the relatively harsher climate – it is thought that operating costs in BC could be around $US20.00 / tonne milled – for a total production cost of $US 30.00/ tonne.

## 6.0 LABOUR MARKET

### 6.1 Open Pit Diamond Mine

- Skilled workers are required for the operation and maintenance of mines in BC – new mines have a high degree of automation and process control requiring fewer, but more highly skilled, operators then in the past.
- For diamond mines a high degree of automation is required to isolate workers from the diamond concentrates to increase security and reduce the risk of theft.
- In 2001 there were approximately 5,200 people directly employed in mines in BC – earning an average salary CA$81,000.[62]
- The first developmental stage – exploration and development, would be expected to take 5 to 10 years (surveying, diamond drilling, metallurgical testwork, pre-feasibility study, bulk sampling, feasibility study, pilot plant, environmental assessment studies and permitting, planning and approvals) – this stage involves a varying number of specialized and contracted personnel.
- Mine and plant construction, would be expected to take 2 years for open pit pre-stripping, requiring 40 workers for 6 months – construction of the process plant, would require 250 workers for 24 months.
- Operation is assumed for 10 years requiring 400 workers.
- Closure would require 2 years for dismantling requiring 50 workers for 6 months and closure preparation requiring 20 workers for 18 months.
- Rehabilitation would be expected to take 4 years requiring about 20 workers.


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| Mine and Processing Plant | Workers |
|---|---|
| Diamond Mine and Plant (Direct) | 400 |
| Indirect Employment (based on Gold Mine) | 472 |
| Induced Employment (based on Gold Mine) | 189 |
| **Total Employment** | **1,061** |

- With the addition of *indirect employment* (employment generated by the suppliers to the primary activity) and *induced employment* (employment created by the respending of employment income), the total employment is estimated to be about 1,061 jobs, based on the BC Input-Output Model employment coefficients

## 7.0 CAPACITY

### 7.1 Mineral Potential

- BC's exploration and development opportunities for diamonds are thought to be small – there is, at present, one known kimberlite occurrence and no known lamproite occurrences in the Province.
- The prospective areas for kimberlite deposits range from the Elkford area and further south to the US border, in the Southeast of the Province.

## 8.0 REGULATORY REGIME

- The regulatory regime applying the NWT diamond operations would likely be relevant for diamond production in BC.
- See section 7.0 Phosphates

## 9.0 GOVERNMENT REVENUES

- The diamond production and processing businesses would be subject to fees and taxes, similar to other businesses – however a revised royalty would likely be introduced.
- The value-added processing of diamonds comes from the cutting and polishing businesses that could emerge from this industry as they have developed in Yellowknife, NWT – this would generate additional downstream employment and corporate income tax, beyond that from the mining of the diamonds alone.
- Some of the fees and taxes that would apply would include:[63]


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**Municipal**
- Business License Fees
- Property Taxes
- Soil Removal Fees

**Provincial**
- Employee Income Taxes (81k/worker, 7%)
- Crown Lands- Land Rent Fee
- Mineral Royalty
- Provincial Sales Tax (7.5%)
- Corporate Income Tax- (13.5%)
- WCB (0.33% wage rate)
- Fuel tax

**Federal**
- Employee income taxes (81k/worker, 14%)
- Employment Insurance (3.15%)
- Corporate income taxes (26.12%)
- Goods and Service Tax (7.0% on margin)
- Federal Excise Tax on fuel

# 10.0 INPUT-OUTPUT TABLE

## 10.1 Demand Coefficients

- Although, most diamonds produced are industrial grades, almost all the value from diamonds is generated from gem grade stones – value of the gem grade stones is largely driven by strategic marketing and recently through market differentiation (e.g. Canadian diamonds being conflict free diamonds).

## 10.2 Employment Coefficients[64]

- The BC Input-Output Model does not provides employment coefficients for diamond production, however BC gold mining coefficients may be comparable.
- As shown below, the direct employment for a new diamond mine (i.e., gold mine) is estimated to be 1.40 jobs per $1,000,000 in revenues.

| Employment/million sales /yr at pit | Direct | Indirect | Induced | Total |
|---|---|---|---|---|
| Diamond Mine (based on Gold Mining)) | 1.40 | 1.66 | 0.66 | 3.72 |

- Direct Employment – is the employment associated with the direct activity.
- Indirect Employment – is the employment generated within the BC economy from suppliers of the goods and services required to produce the primary product.


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- Induced Employment – is generated from the suppliers paying out wages to their employees, which are then respent in the economy (net of savings and taxes).
- Total Employment – is the sum of this total economic activity, (i.e., direct and spin-off impacts) composed of three components (direct, indirect and induced).

## 10.3 Labor and Capital Intensity

- The employment coefficients above reflect the relative labor intensity of the industrial mineral activity – low labor intensity generally reflects a higher capital intensity in an industry, and higher labor productivity per worker.
- Firms attempt to equalize the productivity from both capital and labor, which allows them to stay competitive and sustain operations (e.g., protect employment) during the ups and down of commodity price cycle.


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## SOURCES OF INFORMATION

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[60] Bort is a gray to black massive diamond, the color of which is caused by inclusions and impurities. The name is also applied to badly coloured, flawed or irregularly shaped diamond crystals that are unsuited for gem purposes. Drilling bort is composed of small, round stones averaging 20 to the carat and is used in diamond drill bits. Crushing bort the lowest grade of diamonds is crushed in steel mortars and graded into abrasive grits of various sizes. 75 % of the world's crushing bort comes from the Congo (Kinshasa). Its chief use is in the manufacture of grinding wheels for sharpening cement carbide, and metal-cutting tools. Dies are single diamonds that they drill holes through and use them as "dies" for pulling copper through in the manufacture of wire.

[61] Based in London, UK, the Diamond Trading Company is the rough diamond-marketing arm of the DeBeers Group. It sources diamonds from the DeBeer's diamond mines and through agreements with other mining companies in Russia and Canada – in total it controls about $^{2}/_{3}^{rds}$ of the world's rough diamonds.

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